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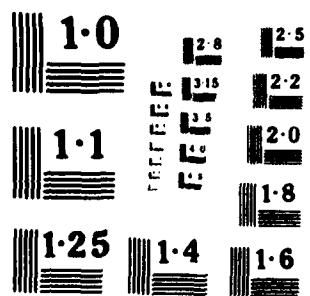
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Structures Technical Memorandum 376

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TENSILE AND FRACTURE TOUGHNESS PROPERTIES
OF MIRAGE III SPARS

by

W.F. LUPSON and J.Y. MANN

SUMMARY

Tensile and fracture toughness tests were conducted on specimens manufactured from the flange portions of the main spars of seven Mirage III wings. These have provided specific information relating to the mechanical properties of this component at locations close to where fatigue cracking occurred in service.



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1. INTRODUCTION

The discovery of fatigue cracks at bolt holes in the inboard lower rear flange section of the main spar of Mirage III wings (Fig. 1) led to extensive investigations dealing with the safe operation of the structure (Refs 1, 2) and the development of methods for improving the fatigue life of the spar (Refs 3, 4).

Some information on the tensile and fracture toughness properties of a III wing spar was available from tests made after the completion of a full-scale wing fatigue test at ARL. Subsequently, pieces of the spars from a number of crashed aircraft were examined (Ref. 5). Some of these have now been used to provide additional strength data at locations close to the bolt holes which were most prone to in-service fatigue cracking.

2. LOCATION OF TEST SPECIMENS

The Mirage III main spar is a large forging in aluminium alloy A-U4SG and, in the fully-machined condition, has a length of 1675 mm. Figure 2 illustrates a finished spar with the lower flange at the bottom. Portions of the spars from the five wings listed in Table 1 were used to provide tensile specimens (11.3 mm test section diameter), and compact tension fracture toughness specimens of 25.4 mm thickness. Details of the specimen locations in each case are given in Fig. 3. However, because of the small piece of material available, no tensile specimens were taken from the spar of CAC-69L. With the exception of the specimens cut from the spar of CAC-69R they were taken from the lower flange of the spar. Those from CAC-69R were taken from the upper flange.

TABLE 1 - IDENTIFICATION OF SPARS

Manufacturer's Serial Number	CAC Wing Number	Laboratory Code
E1321-UB521	CAC-69L	JC
E1220-UB498	CAC-78R	JD
E1270-UB500	CAC-78L	JE
E1397-UB558	CAC-104R	JF
E1216-UB493	CAC-69R	JG

The crack starter notches in the fracture toughness specimens were all oriented in a chordwise direction relative to the spar.

3. TEST RESULTS

Individual tensile and fracture toughness results are given in Tables 2 and 3 respectively, together with those for the spar in the ARL full-scale fatigue test wing. Table 2 also gives the tensile test results for two specimens taken in a longitudinal direction from the upper flange of a spar tested at the Eidgenössisches Flugzeugwerk (F+W), Switzerland (Ref. 6).

During the course of the ARL investigation to develop life-enhancement techniques for the Mirage III main spar several batches of thick rolled plate in A7-U4SG-T651 alloy (a later variant of A-U4SG) were used for the manufacture of fatigue test specimens. The average properties of these batches are given in Table 4 (Ref. 4).

TABLE 2 - TENSILE TEST RESULTS

Specimen Number	0.1% PS (MPa)	0.2% PS (MPa)	UTS (MPa)	Elongation (%)		0.2% PS UTS
				5.65 \sqrt{A}	4 \sqrt{A}	
♦ Specification A-U4SG-T6 or A-U4SG-T651	-	380	450	8	-	[0.84]
JD3	454	464	517	12.1	-	0.90
JE3	438	451	503	8.0	-	0.90
JF3	459	465	512	8.9	10.0	0.91
JG3	422	431	485	10.0	12.5	0.89
Average	443	453	504	9.8	11.3	0.90
Standard Deviation	17	16	14	1.8	1.8	0.01
<u>Spar of ARL test wing</u>						
	452	462	514	7.5	7.4	0.90
	452	461	514	8.7	8.9	0.90
	461	475	522	7.5	7.2	0.91
Average	455	466	517	7.9	7.8	0.90
Standard Deviation	5	5	8	0.7	0.9	0.01
<u>Spar of F+W test wing*</u>						
	-	440	480	11.2	-	0.92
	-	460	497	10.7	-	0.93
Average	-	450	489	11.0	-	0.92
<u>All spars</u>						
Average	448	457	505	9.4	9.2	0.90

♦ Conditions de controle des produits filés et étirés en alliages d'aluminium utilisés dans les constructions aéronautiques. Ministère de la Défense, Direction Technique des Constructions Aéronautiques AIR 9049, Edition no. 1, 30 April 1982, pp. 35,37.

* From upper flange.

TABLE 3 - FRACTURE TOUGHNESS

Specimen Number	Fracture toughness, K_{Ic} (MPa.m ^{3/2})
<u>Spars from crashed aircraft</u>	
JC1 } JC2 }	} invalid results
JD1 } JD2 }	32.2 34.2
<u>average</u>	33.2
JE1 } JE2 }	35.7 32.1
<u>average</u>	33.9
JF1	overloaded during fatigue cracking
JF2	37.5
<u>average</u>	37.5
* JG1 } * JG2 }	31.3 31.5
<u>average</u>	31.4
average (crashed wings)	33.5
standard deviation	2.4
<u>Spar of ARL test wing</u>	
* M1 } * M2 }	31.1 27.7
<u>average</u>	29.4
M3	29.7
average (test wing)	29.5
standard deviation	1.7
<u>All spars</u> average	32.3

* From upper flange

TABLE 4 - PROPERTIES OF A7-U4SG-T651 TEST MATERIAL

Batch Number	0.1% PS (MPa)	0.2% PS (MPa)	UTS (MPa)	Elongation (%) 5.65 \sqrt{A}	0.2% PS UTS	Fracture toughness, K_{Ic} (MPa.m $^{1/2}$)
GK	441 (3)*	446 (4)	446 (2)	10.1 (0.4)	0.91	30.3 (0.5)
GN	445 (4)	451 (3)	493 (11)	12.3 (0.4)	0.91	33.2 (1.2)
GT	450 (6)	455 (6)	497 (7)	11.4 (1.3)	0.92	32.4 (1.8)
GZ	451 (3)	458 (2)	509 (6)	11.5 (0.5)	0.90	32.0 (0.5)
Overall average	448	454	498	11.7	0.91	32.0

* Figures in parentheses are standard deviations.

These average figures are not significantly different to these for "all spars" listed in Tables 2 and 3.

4. CONCLUDING REMARKS

Based on the results presented in the Memorandum the average mechanical properties of the flange of the main spar of the Mirage III aircraft at the root end are:

0.1% PS	448 MPa
0.2% PS	457 MPa
UTS	505 MPa
Elongation (5.65 \sqrt{A})	9.4%
K_{Ic}	32.3 MPa.m $^{1/2}$

[6]

These values are not significantly different to those of the test material used during an investigation to develop procedures for improving the life of the spar.

ACKNOWLEDGEMENTS

Thanks are expressed to the staff of the Mechanical Testing Laboratory of Structures Division for conducting the tensile and fracture toughness tests.

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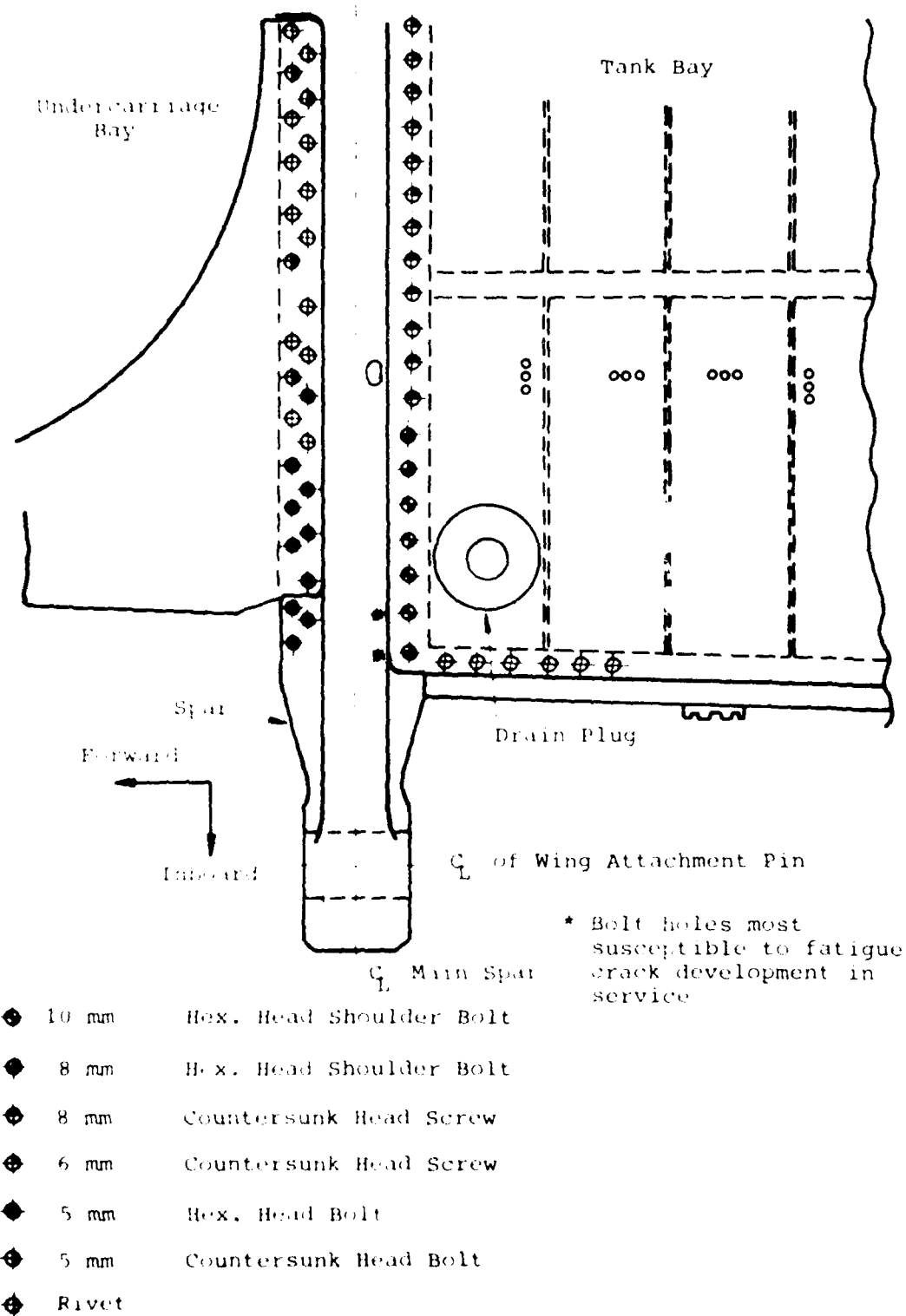


FIG. 1 MIRAGE III PORT WING VIEW FROM LOWER SURFACE

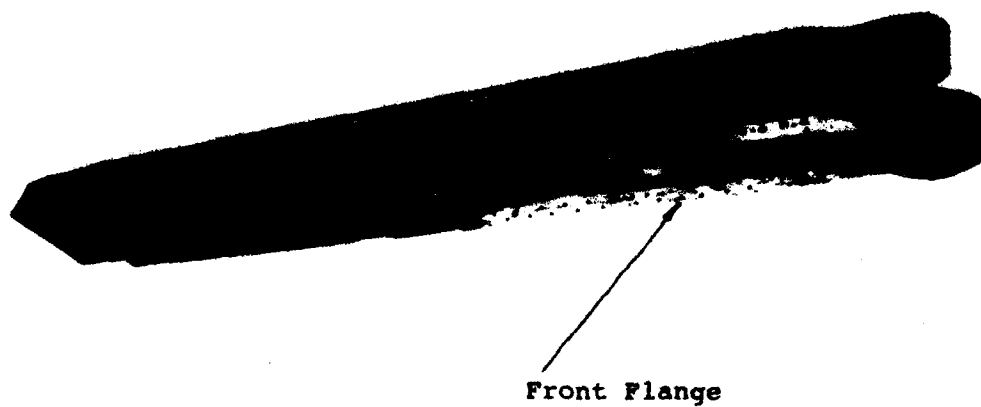


FIG. 2 MIRAGE 1110 MAIN SPAR - LOWER SURFACE AT BOTTOM

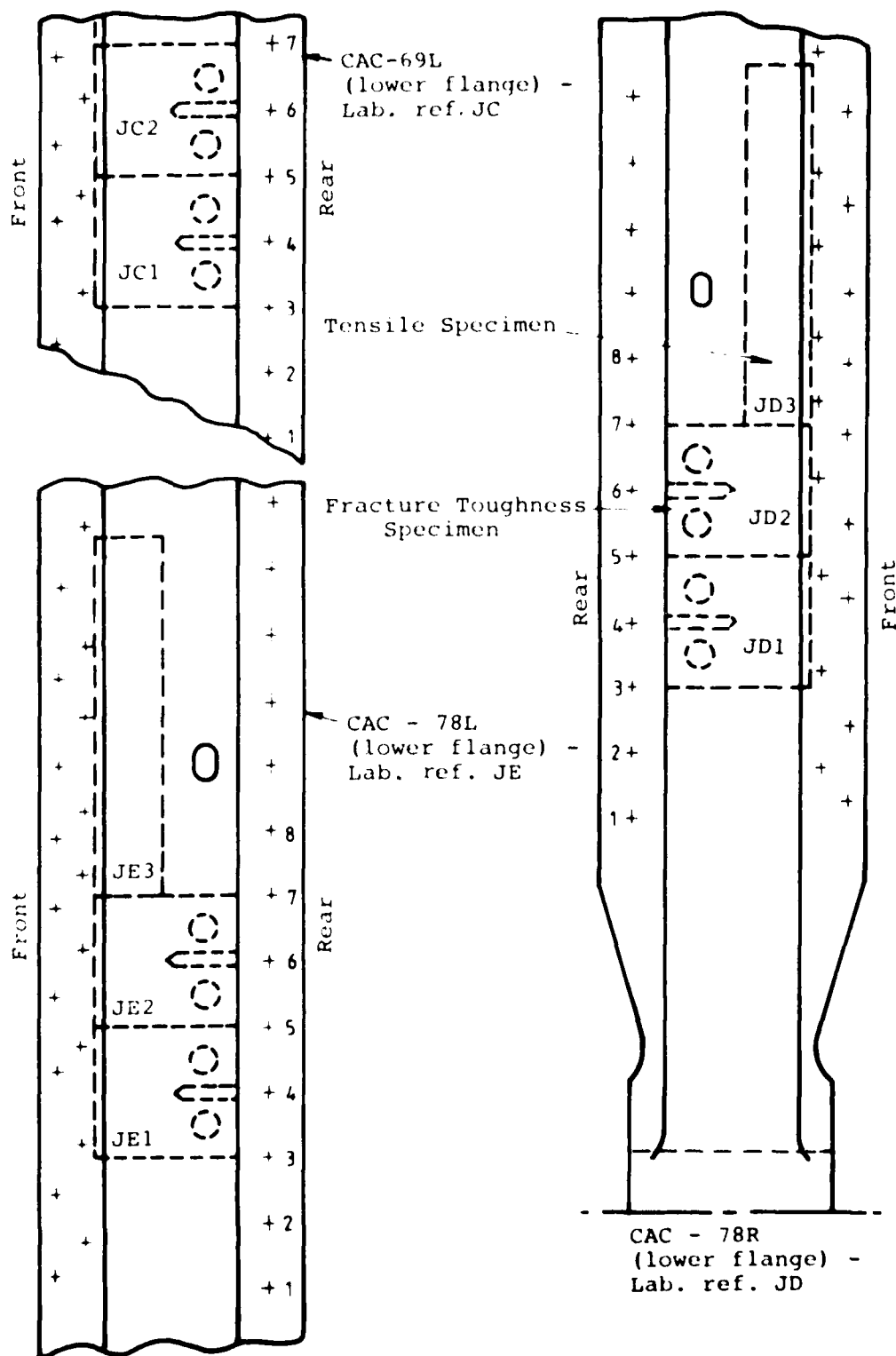


FIG. 3(a) LOCATIONS OF TEST SPECIMENS IN SPARS

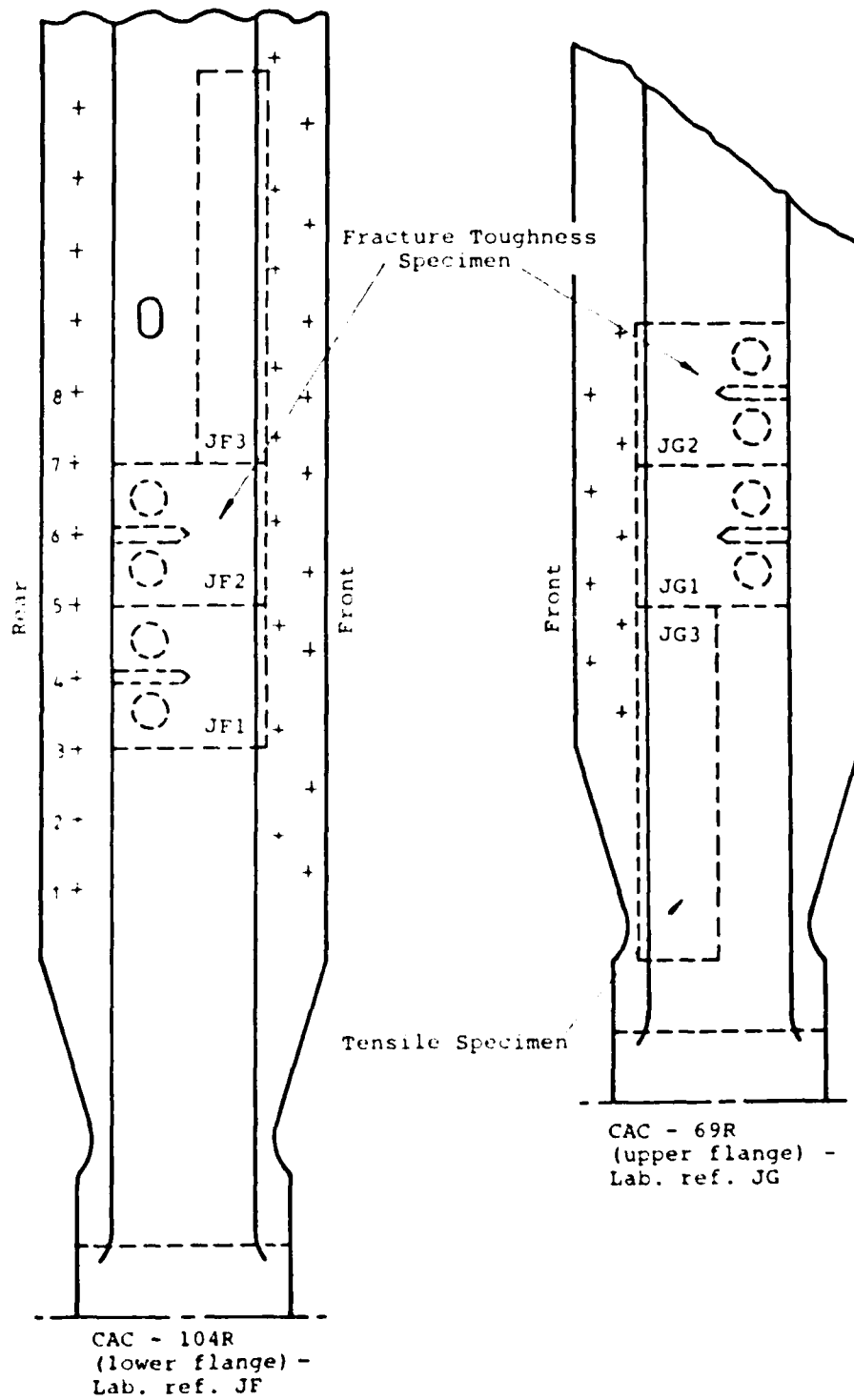


FIG. 3(b) LOCATIONS OF TEST SPECIMENS IN SPARS

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